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**TECHNICAL REPORT  
EP-154**

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**PREDICTION OF SKIN TEMPERATURE  
OF MEN IN THE COLD**

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**QUARTERMASTER RESEARCH & ENGINEERING CENTER  
ENVIRONMENTAL PROTECTION RESEARCH DIVISION**

**JUNE 1961**

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ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report  
EP-154

PREDICTION OF SKIN TEMPERATURE OF MEN IN THE COLD

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Physiology Branch

Project Reference:

June 1961

## FOREWORD

PREDICTION OF MILITARY EFFECTIVENESS NECESSARILY OCCUPIES AN IMPORTANT POSITION IN ANY PROGRAM OF RESEARCH ON MILITARY PHYSIOLOGY. THIS REPORT PRESENTS ONE SMALL BUILDING BLOCK IN THE FOUNDATION FOR SUCH PREDICTION. FROM THE RESEARCH PRESENTED HERE ONE CAN PREDICT THE SKIN TEMPERATURES OF SEMI-NUDE MEN OVER AN IMPORTANT RANGE OF COOL ENVIRONMENTS. THE COMPLETION OF THIS PHASE NOW PERMITS RATIONAL PLANNING OF EXPERIMENTS ON CLOTHED MEN IN COLD ENVIRONMENTS, WHICH WILL LEAD TO ASSIGNMENT OF PROPER WEIGHTING FACTORS FOR INSULATION AND SPECIAL DESIGN OF COLD-WEATHER PROTECTIVE CLOTHING.

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## ABSTRACT

SKIN TEMPERATURES OF SEMI-NUDE MEN WERE MEASURED DURING 2-HOUR EXPOSURES TO VARIOUS COMBINATIONS OF AIR TEMPERATURE (90 TO 25°F) AND WIND VELOCITIES (< 1, 5, 10 MPH). THE DATA WERE USED TO DERIVE AN EXPRESSION FOR THE ESTIMATION OF MEAN WEIGHTED SKIN TEMPERATURE AS A FUNCTION OF DURATION OF EXPOSURE (UP TO 180 MINUTES), AIR TEMPERATURE (90 TO -20°F), AND WINDSPEED (0 TO 40 MPH). A CHART WAS ALSO CONSTRUCTED FOR MORE RAPID ESTIMATION OF SKIN TEMPERATURE.

## PREDICTION OF SKIN TEMPERATURE OF MEN IN THE COLD

### 1. INTRODUCTION

CONSIDERABLE EFFORT HAS BEEN CHanneLED INTO STUDIES OF THE PHYSIOLOGICAL RESPONSES OF MEN DURING ACUTE COLD EXPOSURE (1, 2, 3, 4). MANY OF THESE STUDIES HAVE BEEN CONCERNED WITH RESPONSES TO ONLY ONE, OR AT MOST, A FEW ENVIRONMENTAL CONDITIONS, THUS PRECLUDING THE POSSIBILITY OF DESCRIBING THE PHYSIOLOGICAL RESPONSES FOR A WIDE RANGE OF COLD CONDITIONS AND NOT TAKING INTO CONSIDERATION THE IMPORTANT FACTORS OF BOTH DRY BULB TEMPERATURE AND WINDSPEED. (THE EFFECT OF HUMIDITY ON PHYSIOLOGICAL RESPONSES OF NUDE MEN IN THE COLD HAS BEEN SHOWN TO BE OF LITTLE IMPORTANCE (2, 3).) ADOLPH AND MOLNAR (1) HAVE STUDIED SEVERAL PHYSIOLOGIC PARAMETERS DURING ACUTE COLD EXPOSURE, BUT THE FACT THAT THEIR STUDIES WERE CONDUCTED OUT-OF-DOORS MEANT THAT ENVIRONMENTAL FACTORS (ESPECIALLY WIND) COULD VARY WIDELY EVEN WITHIN SINGLE TESTS. IN A RECENT PAPER WE DESCRIBED THE EFFECTS OF DRY BULB TEMPERATURE AND WINDSPEED ON SHIVERING HEAT PRODUCTION OF NEARLY NUDE MEN IN THE COLD (5) THIS PAPER DESCRIBES THE CHANGES IN SKIN TEMPERATURE OF MEN IN THE COLD AND PRESENTS A GRAPHIC METHOD FOR PREDICTING MEAN WEIGHTED SKIN TEMPERATURE AS A FUNCTION OF DRY BULB TEMPERATURE, WINDSPEED, AND DURATION OF EXPOSURE.

### 2. EXPERIMENTAL DESIGN AND METHODS

FROM 6 TO 16 HEALTHY YOUNG MEN (MEAN WEIGHT 70.77 KG.; MEAN SURFACE AREA 1.82m<sup>2</sup>) WERE EXPOSED NUDE (EXCEPT FOR COTTON SHORTS AND, DURING THE MORE SEVERE EXPOSURES, COTTON SOCKS) TO VARIOUS COMBINATIONS OF DRY BULB TEMPERATURE (90 TO 25°F) AND WINDSPEED (< 1, 5, 10 MPH); RELATIVE HUMIDITY WAS MAINTAINED AT 50%. SIX MEN AT A TIME WERE EXPOSED TO A GIVEN SET OF CONDITIONS. EXPOSURE TO EACH CONDITION WAS LIMITED TO 2 HOURS, BUT WAS LESS THAN 2 HOURS FOR THE MORE SEVERE CONDITIONS. EXPOSURE WAS PRECEDED BY 1 HOUR AT A COMFORTABLE TEMPERATURE (CONTROL, 80°F, 50% RH, AIR MOVEMENT < 20 FT/MIN). SUBJECTS REPORTED AT 0800 IN THE FASTING STATE. DURING CONTROL AND EXPERIMENTAL PERIODS THE SUBJECTS WERE IN A SEMI-RECLINING POSITION. TEMPERATURES WERE MEASURED CONTINUOUSLY AT 11 POINTS ON THE SKIN BY MEANS OF COPPER-CONSTANTAN THERMOCOUPLES TIED IN PLACE WITH ELASTIC THREAD. POINTS MEASURED WERE: BIG TOE AT BASE OF NAIL, INSTEP, CALF, MEDIAL THIGH, LATERAL THIGH, BACK, CHEST, UPPER ARM, LOWER ARM, LITTLE FINGER AT BASE OF NAIL, AND FOREHEAD. MEAN WEIGHTED SKIN TEMPERATURE WAS RECORDED AS THE SUM OF 10 WEIGHTED POINTS (EXCLUDING THE TOE POINT) AS FOLLOWS: .05 INSTEP; .15 CALF; .125 LATERAL THIGH; .125 INNER THIGH; .125 BACK; .125 CHEST; .07 UPPER ARM; .07 LOWER ARM; .06 FINGER; .10 FOREHEAD.

### 3. RESULTS

#### A. EFFECT OF WIND AND DRY BULB TEMPERATURE ON SKIN TEMPERATURE

MEAN WEIGHTED SKIN TEMPERATURES ARE SHOWN IN FIGURE 1 FOR ALL CONDITIONS STUDIED. EXPOSURES AT THE 3 WINDSPEEDS ARE PLOTTED SEPARATELY



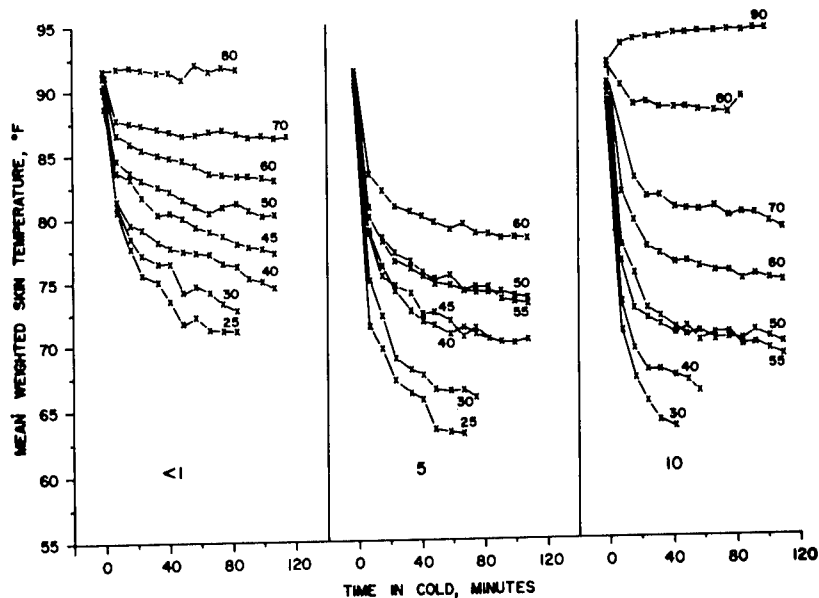


FIGURE 1: MEAN WEIGHTED SKIN TEMPERATURE OF MEN DURING EXPOSURE TO VARIOUS AMBIENT CONDITIONS. NUMBERS ON CURVES, AIR TEMPERATURE (°F); NUMBERS AT BOTTOM OF EACH SECTION, WIND VELOCITY (MPH).

FOR PURPOSES OF CLARITY. SKIN TEMPERATURE REMAINED CONSTANT DURING EXPOSURE TO 80/< 1 (AIR TEMPERATURE, °F/WIND VELOCITY, MPH), INCREASED SLIGHTLY AT 90/10, AND DECREASED DURING EXPOSURE TO ALL OTHER CONDITIONS. THE CHANGES IN SKIN TEMPERATURE WERE RAPID DURING THE FIRST 20 MINUTES OF EXPOSURE (75-100% OF THE TOTAL CHANGE OCCURRED DURING THIS TIME) AND SLOWER DURING THE REMAINDER OF EXPOSURE. THE SLOW PHASE WAS ESSENTIALLY LINEAR WITH TIME. INCREASING THE WINDSPEED HAD THE EFFECT OF CAUSING LARGER INITIAL CHANGES IN SKIN TEMPERATURE, I.E., THE PERCENTAGE CHANGE IN SKIN TEMPERATURE DURING THE FIRST 20 MINUTES WAS SOMEWHAT GREATER WITH THE HIGHER WINDSPEEDS. WHEN WIND WAS INCREASED AT A GIVEN AMBIENT TEMPERATURE, SKIN TEMPERATURE FELL TO A LOWER VALUE. FOR EXAMPLE, SKIN TEMPERATURE AFTER 60 MINUTES OF EXPOSURE AT 60/< 1 WAS 84°F, AT 60/5, 79°F AND AT 60/10, 76°F. FIGURE 2 SHOWS THE RELATIONSHIP BETWEEN SKIN TEMPERATURE AND DRY BULB TEMPERATURE AFTER 60 MINUTES OF EXPOSURE. THERE IS A LINEAR RELATIONSHIP BETWEEN SKIN TEMPERATURE AND AIR TEMPERATURE FOR EACH OF THE WINDSPEEDS STUDIED (1) (WE HAVE INCLUDED POINTS FROM 2 SEPARATE EXPOSURES AT 3 AND 30 MPH). FIGURES 2 AND 3A INDICATE, AS WOULD BE EXPECTED, THAT INCREASING THE WINDSPEED DOES NOT HAVE THE SAME EFFECT ON SKIN TEMPERATURE AT ALL AIR TEMPERATURES (NON-LINEARITY). FOR EXAMPLE, INCREASING THE WINDSPEED FROM 5 TO 10 MPH AT AN AIR TEMPERATURE OF 40°F LOWERED SKIN TEMPERATURE 4.5°F, WHILE THE SAME INCREMENT IN WINDSPEED AT 70°F LOWERED SKIN TEMPERATURE ONLY 1.3°F. WHEN THE SQUARE ROOT OF WINDSPEED IS PLOTTED AGAINST SKIN TEMPERATURE (1) AT A GIVEN AIR TEMPERATURE, A LINEAR RELATION IS ESTABLISHED (FIG. 3B).

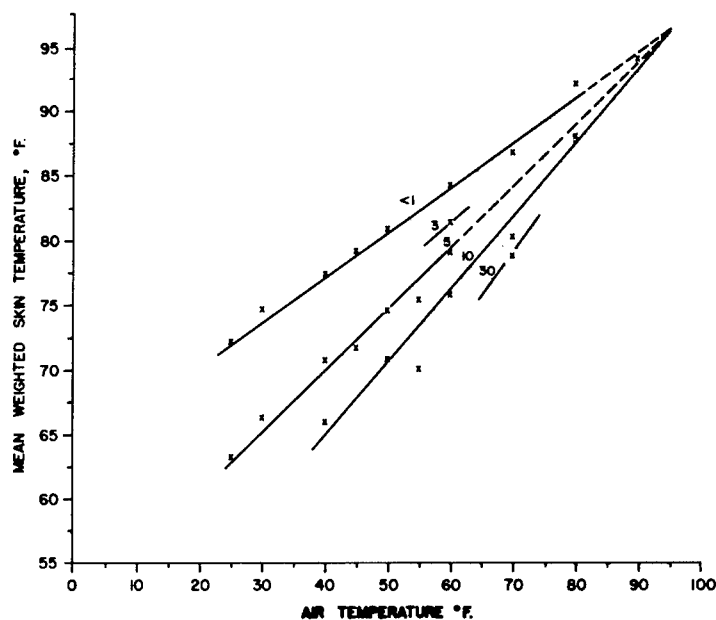


FIGURE 2: MEAN WEIGHTED SKIN TEMPERATURE OF MEN AFTER 60 MINUTES EXPOSURE TO VARIOUS AMBIENT CONDITIONS. NUMBERS ON EACH CURVE REFER TO WIND VELOCITY (MPH). DASHED PORTION OF CURVE, EXTRAPOLATION OF DATA.

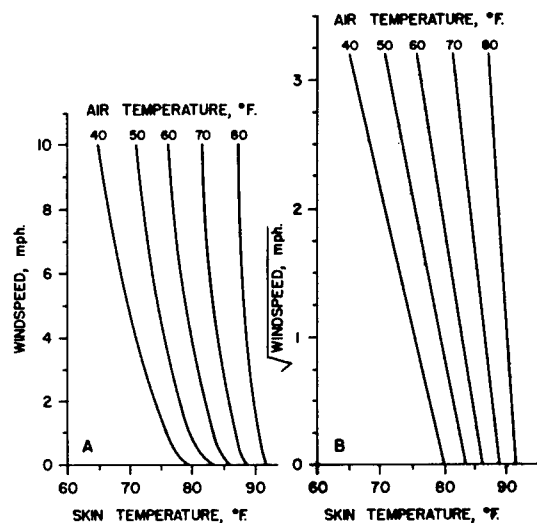


FIGURE 3: A. THE NON-EQUIVALENT EFFECTS OF WIND VELOCITY ON SKIN TEMPERATURE AT VARIOUS AIR TEMPERATURES AFTER 60 MINUTES OF EXPOSURE. B. THE SQUARE ROOT OF WIND VELOCITY VS SKIN TEMPERATURE AFTER 60 MINUTES OF EXPOSURE AT VARIOUS AIR TEMPERATURES. A LINEAR RELATIONSHIP IS ESTABLISHED. SLOPES OF CURVES INDICATE NON-EQUIVALENT EFFECTS OF WIND VELOCITY AT DIFFERENT AIR TEMPERATURES.

THE SLOPES OF THE CURVES, WHICH RANGE FROM  $-.20$  (AT  $40^{\circ}\text{F}$ ) TO  $-.80$  (AT  $80^{\circ}\text{F}$ ), INDICATE THE NON-EQUIVALENT EFFECT OF WINDSPEED AT THE VARIOUS AIR TEMPERATURES.

#### B. PREDICTION OF SKIN TEMPERATURE

AS DESCRIBED EARLIER, THE RELATIONSHIP BETWEEN SKIN TEMPERATURE AND AMBIENT TEMPERATURE WAS LINEAR AND A SEPARATE CURVE WAS ESTABLISHED FOR EACH OF THE WINDSPEEDS STUDIED (FIG. 2). IT WAS APPARENT THAT THESE CURVES CONSTITUTED A SET OF REASONABLY STRAIGHT LINES, AND THAT THEY ALL SEEMED TO GO THROUGH A SPECIFIC POINT, NAMELY, SKIN TEMPERATURE  $96^{\circ}\text{F}$  AND AIR TEMPERATURE  $95^{\circ}\text{F}$  (FIG. 2). IT IS OBVIOUS THAT THESE CURVES SHOULD ALL APPROACH SOME UPPER BOUND ASYMPTOTICALLY, BUT THE CHANGE-OVER FROM THE STRAIGHT LINE TO A SHARP-BREAKING CURVE IS A DIFFICULT TRANSITION MATHEMATICALLY, SO IT WAS ASSUMED THAT THIS UPPER LIMIT REPRESENTED THE UPPER BOUND OF THE VALUES WHICH WOULD HAVE ANY MEANING PHYSICALLY. IT WAS THEN NECESSARY TO DETERMINE THE SLOPE OF ALL THESE STRAIGHT LINES AS A FUNCTION OF WINDSPEED AND ALSO THE TIME THE SUBJECT WAS EXPOSED TO THE PARTICULAR CONDITION. THE EQUATION FOR A HYPERBOLA SEEMED TO BE THE BEST DESCRIPTION OF THE SLOPES AS A FUNCTION OF WINDSPEED AND TIME AS FOLLOWS:

$$(S - A) (WS - B) = C \quad \text{EQUATION 1}$$

WHERE  $S$  IS THE SLOPE OF THE STRAIGHT LINE,  $WS$  IS THE WINDSPEED, AND  $A$ ,  $B$ , AND  $C$  ARE CONSTANTS WHICH MAY OR MAY NOT BE FUNCTIONS OF TIME OF EXPOSURE. THIS SORT OF RELATIONSHIP HAS THE CORRECT LIMITING VALUES AS TIME AND WINDSPEED INCREASE INDEFINITELY, AND ALSO SEEMS TO HAVE THE PROPER OVERALL RELATIONSHIP.

USING THIS FORM OF THE EQUATION, WE MADE A CAREFUL STUDY OF THE BEHAVIOR OF  $A$ ,  $B$ , AND  $C$  AND CAME TO THE CONCLUSION THAT FOR PRACTICAL PURPOSES " $A$ " WAS THE ONLY COEFFICIENT WHICH WAS A FUNCTION OF TIME. THIS IS REASONABLE, IN THAT THE BEHAVIOR OF THE SLOPE AS A FUNCTION OF WINDSPEED SHOULD BEAR THE SAME RELATIONSHIP TO ALL SLOPES IRRESPECTIVE OF TIME AND THE ONLY EFFECT OF TIME WOULD BE TO MOVE ALL CURVES UP OR DOWN TOGETHER. IT TURNED OUT THAT " $C$ " HAD THE VALUE OF  $-9.18$ , " $B$ " THE VALUE  $-15.2$  AND " $A$ " WAS EQUAL TO  $\frac{1.066 T + 57.1}{T + 70.7}$  WHERE " $T$ " IS TIME OF EXPOSURE IN MINUTES.

WHEN THESE VALUES ARE SUBSTITUTED IN EQUATION 1 WE OBTAIN:

$$\left( S - \frac{1.066 T + 57.1}{T + 70.7} \right) (WS + 15.2) = -9.18 \quad \text{EQUATION 2}$$

OR

$$S = \frac{1.066 T + 57.1}{T + 70.7} = \frac{-9.18}{WS + 15.2} \quad \text{EQUATION 3}$$

SINCE THE SLOPE OF A STRAIGHT LINE IS  $S = \frac{Y}{X}$ , WHERE  $X$  = AIR TEMPERATURE ( $T_A$ ) AND  $Y$  = SKIN TEMPERATURE ( $T_S$ ), WE MAY SUBSTITUTE  $\frac{T_S}{T_A}$  FOR  $S$  IN EQUATION 3.

$$\frac{T_S}{T_A} = \frac{1.066 T + 57.1}{T + 70.7} - \frac{9.18}{WS + 15.2} \quad \text{EQUATION 4}$$

WE STATED THAT THE UPPER LIMITS FOR  $T_A$  AND  $T_S$  WERE 95 AND 96°F, RESPECTIVELY. THEREFORE, THESE LIMITS APPLIED TO EQUATION 4 AND REARRANGED GIVE:

$$(96 - T_S) = \frac{1.066 T + 57.1}{T + 70.7} - \frac{9.18}{WS + 15.2} (95 - T_A) \quad \text{EQUATION 5}$$

IT SEEMED LOGICAL THAT THIS MODEL WOULD HOLD OVER REGIONS WHICH WERE NOT INCLUDED IN THE DATA, BUT WHICH WERE USED TO DETERMINE THESE CONSTANTS. CONDITIONS NOT INCLUDED IN THE DATA HAVE SINCE BEEN STUDIED AND GOOD AGREEMENT WAS FOUND BETWEEN PREDICTED AND OBSERVED SKIN TEMPERATURES. THERE ARE, OF COURSE, CERTAIN SHORT-COMINGS AND LIMITATIONS TO THIS MODEL. WHEN EXPOSURE TIME IS VERY SHORT (LESS THAN 10 MINUTES) AND AIR TEMPERATURE IS LOW, THE EQUATION TENDS TO GIVE LOWER VALUES FOR  $T_S$  THAN ARE ACTUALLY OBSERVED. THE MODEL ALSO DOES NOT PREDICT ANY SKIN TEMPERATURE ABOVE 96°F, NOR DOES IT ACCOMMODATE ITSELF TO PRE-EXPOSURE CONDITIONS OTHER THAN THOSE USED IN OUR STUDY (DB 80°F, RH 50%, AIR MOVEMENT < 20 FT/MIN). THEREFORE, IT IS ESSENTIAL THAT THE INITIAL TRANSIENT STATE DIE OUT BEFORE THESE RELATIONSHIPS WILL HOLD. THIS MEANS THAT THE SUBJECT MUST BE EXPOSED TO THE EXPERIMENTAL CONDITIONS LONG ENOUGH TO OVERCOME ANY DIFFERENCES IN HIS PRE-EXPOSURE STATE.

A CHART (FIG. 4) WAS DRAWN BASED ON THE RELATIONSHIPS DESCRIBED. IN ORDER TO PROCEED FROM ONE SECTION OF THE CHART TO THE OTHER, A VALUE "K" WAS DETERMINED FOR EACH WINDSPEED/TIME CURVE IN THE LEFT SECTION OF THE CHART. THE VALUE FOR "K" HAS NO MEANING AND IS USED ONLY AS AN INSTRUMENT FOR GRAPHICAL PRESENTATION OF THE PREDICTION EQUATION. THE CHART ALLOWS FOR RAPID ESTIMATION OF SKIN TEMPERATURE FOR EXPOSURE TIMES UP TO 3 HOURS, AIR TEMPERATURE DOWN TO -20°F, AND WINDSPEEDS UP TO 40 MPH.

### C. TOLERANCE TIMES

ALTHOUGH THESE STUDIES WERE NOT CONDUCTED FOR THE PURPOSE OF OBTAINING TOLERANCE TIMES FOR NUDE MEN IN THE COLD, WE HAVE BEEN ABLE TO PUT TOGETHER INFORMATION ON SKIN TEMPERATURES, INVESTIGATORS' SUBJECTIVE EVALUATION OF THE CONDITION OF THE TEST SUBJECTS, AND THE SUBJECTS' OPINIONS CONCERNING THE LENGTH OF TIME THEY FELT THEY COULD TOLERATE THE CONDITIONS INTO A CHART FOR PREDICTING APPROXIMATE TOLERANCE TIMES. IT APPEARS THAT THERE IS A COINCIDENCE BETWEEN THOSE CONDITIONS WHICH COULD BE TOLERATED FOR 2 HOURS (THE MAXIMUM LENGTH OF TIME THE TESTS WERE RUN) AND A CRITICAL SKIN TEMPERATURE. WHEN SKIN TEMPERATURE DID NOT FALL BELOW 70°F, THE CONDITIONS WERE TOLERABLE FOR 2 HOURS OR

From the left section of chart, given values of Wind Speed (mph) and Exposure Time in Minutes determine a value "K." The same "K" and a given Ambient Temperature (°F) on right side of chart, determine the Mean Weighted Skin Temperature (°F).

**EXAMPLE:**

WINDSPEED IS 10 mph, EXPOSURE TIME IS 50 MINUTES, AND AMBIENT TEMPERATURE IS 40°F. ENTER ORDINATE OF LEFT CHART AT 10 mph AND ABSCISSA AT 50 MINUTES. A VALUE OF .55 IS FOUND FOR "K". ENTER ORDINATE OF RIGHT CHART AT .55 AND ABSCISSA AT 40°F. A VALUE OF 66°F IS FOUND FOR MEAN WEIGHTED SKIN TEMPERATURE

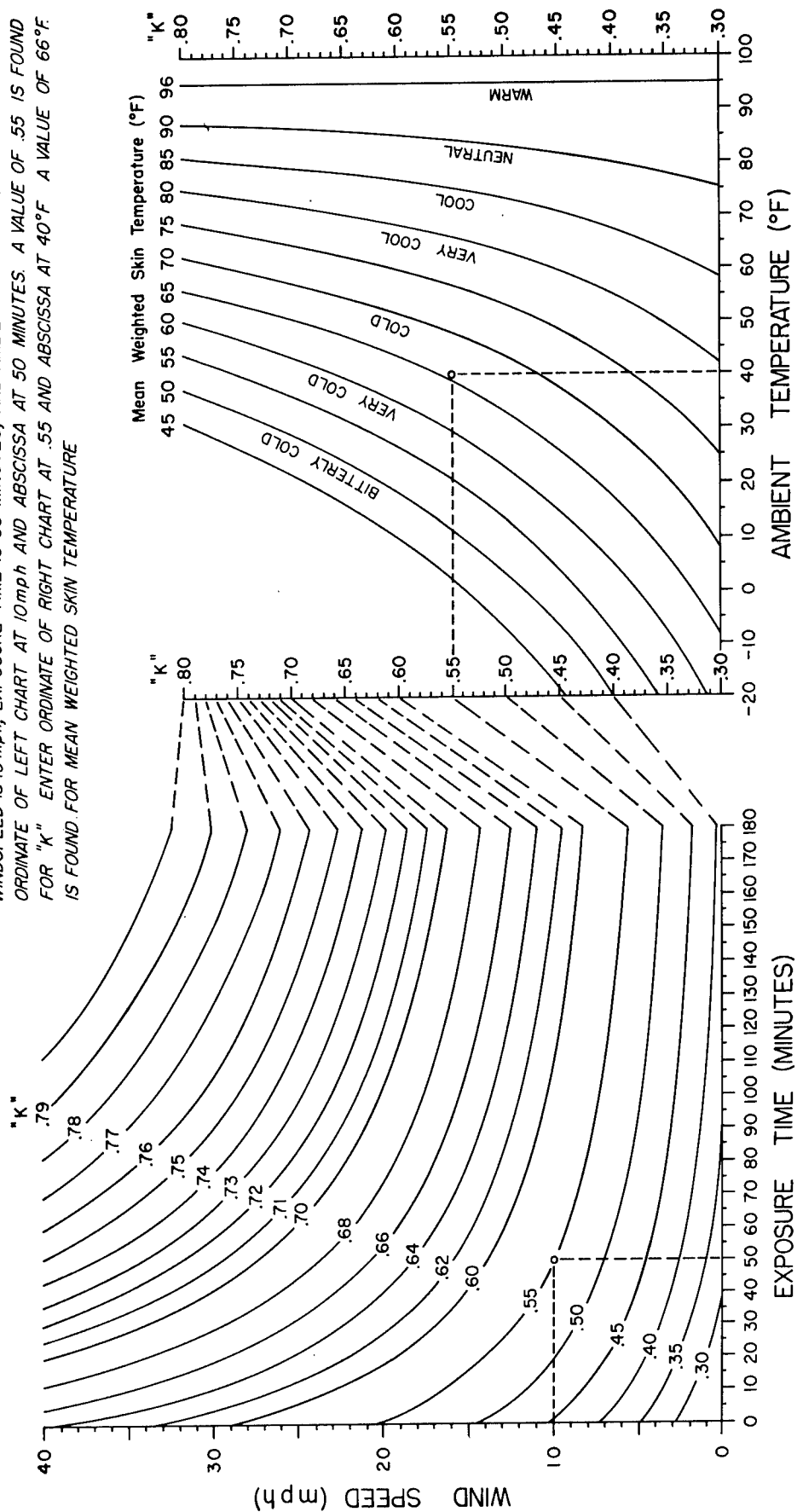


FIGURE 4: CHART FOR PREDICTING MEAN WEIGHTED SKIN TEMPERATURE OF NUDE MEN IN THE COLD. USE OF GRAPH IS EXPLAINED AT TOP OF CHART.

LONGER (FIG. 1). WHEN MEAN WEIGHTED SKIN TEMPERATURE FELL BELOW  $70^{\circ}\text{F}$ , THE CONDITIONS COULD BE TOLERATED FOR LESS THAN 2 HOURS, DEPENDING ON HOW LOW SKIN TEMPERATURE FELL. IT MUST BE REMEMBERED THAT DURING THE MOST SEVERE CONDITIONS COTTON SOCKS WERE WORN TO PROTECT THE TOES FROM PAIN AND FROSTBITE AND THE SUBJECTS WERE ALSO ALLOWED TO PROTECT FINGERS BY PLACING THEM UNDER THEIR ARMS. IF THESE PRECAUTIONS HAD NOT BEEN TAKEN, IT IS POSSIBLE THAT THE SUBJECTS WOULD HAVE BEEN REMOVED FROM THE CHAMBER SOONER DURING SOME OF THE MORE SEVERE EXPOSURES. RECOGNIZING THESE LIMITATIONS, AND ALSO THE LIMITATION OF SUBJECTIVE EVALUATIONS OF TOLERANCE, WE HAVE CONSTRUCTED A CHART (FIG. 5) WHICH SHOWS APPROXIMATE TOLERANCE TIMES FOR COMBINATIONS OF WINDSPEED (TO 10 MPH) AND DRY BULB TEMPERATURE (TO  $-15^{\circ}\text{F}$ ). MEAN WEIGHTED SKIN TEMPERATURE AT EACH TOLERANCE TIME IS INDICATED ON EACH CURVE. THE CHART IS CONSTRUCTED IN PART FROM INFORMATION IN FIGURE 4, I.E., THE TIMES REQUIRED TO REACH GIVEN SKIN TEMPERATURES FOR VARIOUS ENVIRONMENTAL CONDITIONS ARE TAKEN FROM THE CHART. FIGURE 5 SHOWS THAT ALL COMBINATIONS OF CONDITIONS TO THE RIGHT OF THE  $T_s 70$  CURVE MAY BE TOLERATED FOR LONGER THAN 2 HOURS, WHILE COMBINATIONS TO THE LEFT OF THE  $T_s 70$  CURVE HAVE TOLERANCE TIMES LESS THAN 2 HOURS. THUS,  $40/10$ ,  $32/5$ , AND  $11/<1$  CAN BE TOLERATED FOR 80 MINUTES AND SKIN TEMPERATURE AT THE END OF THAT TIME WILL BE  $65^{\circ}\text{F}$ .

#### 4. COMMENT

SKIN TEMPERATURE IS ONE OF THE MOST RELIABLE INDEXES OF THE EFFECTS OF COLD ENVIRONMENTS ON THE SEMI-NUDE MAN. THIS WAS POINTED OUT BY ADOLPH AND MOLNAR (1) SEVERAL YEARS AGO. RECTAL TEMPERATURE, OXYGEN CONSUMPTION, AND PULSE RATE MAY BE USEFUL INDEXES OVER LIMITED RANGES OF CLIMATIC CONDITIONS, BUT ARE NOT AS SENSITIVE AS MEAN SKIN TEMPERATURE OVER WIDER RANGES OF CONDITIONS.

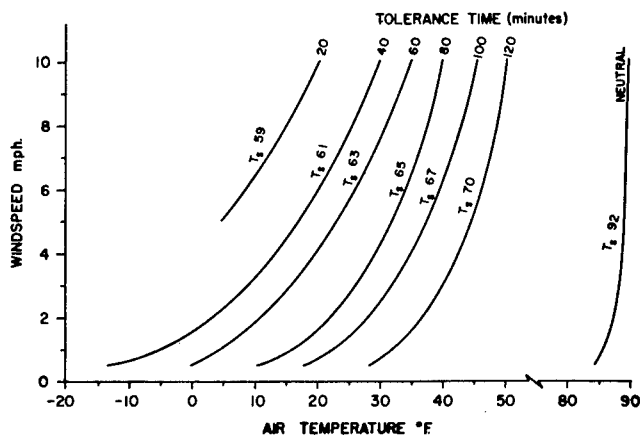


FIGURE 5: TOLERANCE TIMES OF SEMI-NUDE MEN EXPOSED TO VARIOUS AMBIENT CONDITIONS. NUMBERS ON CURVES REFER TO SKIN TEMPERATURE ( $T_s$ ) AT THAT TOLERANCE TIME. SEE TEXT FOR EXAMPLES.

ALTHOUGH WE HAVE NOT STUDIED THE EFFECTS OF ALL ENVIRONMENTAL FACTORS ON SKIN TEMPERATURE, WE HAVE CONSIDERED THE EFFECTS OF HUMIDITY (3), WIND VELOCITY AND AIR TEMPERATURE. THE EFFECTS OF SOLAR RADIATION WERE STUDIED BY ADOLPH AND MOLNAR (1). THE EFFECTS OF WIND VELOCITY, DRY BULB TEMPERATURE, AND DURATION OF EXPOSURE ON SKIN TEMPERATURE WERE OF SUCH A UNIFORM NATURE THAT WE WERE ABLE TO DERIVE AN EXPRESSION WHICH ALLOWS A GOOD ESTIMATE OF SKIN TEMPERATURE OVER A WIDE RANGE OF THE ABOVE VARIABLES.

IT IS APPARENT THAT CLOTHING, ACTIVITY, DIET, AND

PERHAPS OTHER FACTORS WILL ALTER THE EFFECTS OF WIND VELOCITY, AIR TEMPERATURE, AND SOLAR RADIATION ON SKIN TEMPERATURE. HOWEVER, IT IS NOT UNLIKELY THAT SKIN TEMPERATURE IS ALTERED, AT LEAST FOR SOME OF THE FACTORS, IN A PREDICTABLE MANNER (6). IT SHOULD, THEREFORE, BE POSSIBLE TO INCORPORATE CORRECTIONS FOR SOME OF THESE FACTORS INTO THE EQUATION FOR PREDICTION OF SKIN TEMPERATURE. WE ARE PRESENTLY CONCERNED WITH THE STUDY OF THE EFFECTS OF INSULATION AND ACTIVITY ON SKIN TEMPERATURE OF MEN IN THE COLD.

## 5. ACKNOWLEDGMENTS

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Aberdeen Proving Ground  
Aberdeen, Maryland
- 2 Chief Signal Officer  
Department of the Army  
Washington 25, D. C.  
Attn: Res. & Dev. Div.

## ARMY (Cont)

- 1 Commanding Officer  
Signal Corps Engr. Lab.  
Ft. Monmouth, N. J.
- 1 Office of Chief of Engineers  
Department of the Army  
Temp. Bldg. T-7, Gravelly Point  
Washington 25, D. C.  
Attn: Research & Dev. Div.
- 4 CO, Chemical Warfare Laboratories  
Army Chemical Center, Maryland  
Attn: Technical (AS13) Library
- 1 Chief Chemical Officer  
Department of the Army  
Bldg. T-7, Gravelly Point  
Washington 25, D. C.  
Attn: Res. & Dev. Div.
- 2 CO, Hq., Medical Nutrition Lab.  
Fitzsimons Army Hospital  
Denver, Colorado  
(1-Dr. Friedmann)
- 1 Armed Forces Institute of Pathology  
Washington 25, D. C.
- 1 Chief, Armed Services Medical  
Procurement Agency  
84 Sands St., Brooklyn 1, N. Y.  
Attn: Property Officer  
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- 1 Chief of Transportation  
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- 2 Commanding Officer  
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U. S. Army  
Ft. Eustis, Virginia  
Attn: Tech Services Dir.
- 1 The Army Library  
Pentagon Bldg.,  
Washington 25, D. C.
- 1 Commandant, Command & General Staff  
College  
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West Point, New York
- 1 Commanding Officer, Detroit Arsenal  
28251 Van Dyke St., Centerline, Mich.  
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- 1 Commanding General  
Hqs., U. S. Army Medical R&D Command  
Main Navy Bldg.  
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Attn: NP&PP Research Branch
- 2 Commander  
QM Intelligence Agency, U.S. Army  
Washington 25, D. C.
- 2 Executive Director  
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Airborne Systems Test Div.  
Yuma Test Station  
Yuma, Arizona

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School  
Fort Greeley, Alaska
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(1 DC/S Material, 1 DC/S Dev.)
- 1 Director  
Air University Library, Attn: 7575  
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- 2 Commandant  
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Randolph Field, Texas
- 1 Commander, Arctic Aeromedical Lab  
APO 731, Seattle, Washington
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Andrews AF Base, Washington 25, D.C.
- 1 Commander  
Wright Air Development Center  
Wright Patterson AF Base, Ohio  
Attn: Tech Library
- 1 Commander  
Strategic Air Command  
Offutt AF Base, Nebraska
- 1 Chief, Nutrition Div.  
Air Development Center  
Aero-Medical Lab.  
Wright Patterson AFB, Ohio  
Attn: Dr. Harry C. Dyme
- 1 Commander  
AF Cambridge Research Center  
Air Research & Development Cmd.  
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## NAVY

- 1 Director  
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4th & Chesapeake St., S. W.  
Washington 25, D. C.
- 1 Chief, Bureau of Ordnance  
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Washington 25, D. C.  
Attn: R&D Div.
- 1 Naval Medical Research Institute  
National Naval Med. Res. Center  
Bethesda, Md.
- 2 Chief of Naval Research  
Washington 25, D. C.  
Attn: Code 402S
- 1 Chief, Bureau of Ships  
Department of the Navy  
Washington 25, D. C.  
Attn: Code 231
- 1 Chief, Bureau of Med. & Surgery  
Dept. of the Navy, Wash 25, D. C.  
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- 1 Commander, U. S. Naval Ord. Test  
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Attn: Code 753
- 1 Chief, Bureau of Aeronautics  
Dept. of the Navy, Wash 25, D. C.  
Attn: Code AE 52
- 1 Chief, Bureau of Supplies & Accounts  
Department of the Navy  
Washington 25, D. C.

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- 1 C.G., U.S. Continental Army Command  
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Ft. Sill, Okla.  
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## BOARDS & COMMITTEES

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- 1 Armed Forces Post Control Bd.  
Walter Reed Army Med. Center  
Forest Glen Annex  
Main Bldg.  
Forest Glen, Maryland
- 1 Army Research Committee  
Chief, Research & Development  
Pentagon, Washington, D. C.

## MISCELLANEOUS

- 1 National Research Council  
2101 Constitution Ave., Washington, D.C.  
Attn: Advisory Bd. on QM R&D
- 10 Armed Services Technical Information Agency  
Arlington Hall Station  
Arlington 12, Va.  
Attn: TIPDR
- 2 Gift and Exchange Division  
Library of Congress  
Washington 25, D. C.
- 1 U. S. Department of Commerce  
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- 1 Central Intelligence Agency  
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Festningen  
Oslo, Norway
- 1 Marine Corps Equipment Board  
Marine Development Center  
Marine Corps School  
Quantico, Va.
- 1 Office of Technical Services  
U. S. Department of Commerce  
Washington 25, D. C.  
Attn: Tech Rpts Sec (THRU OQMG)
- 1 U. S. Department of Agriculture Library  
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Industrial College of the Armed Forces  
Ft. McNair, Washington 25, D. C.
- 1 QM Representative  
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Ft. Leavenworth, Kansas



<p>AD- Div. 28 Accession No.</p> <p>Quartermaster Research &amp; Engineering Center, Natick, Mass. PREDICTION OF SKIN TEMPERATURE OF MEN IN THE COLD by P. F. Lampietro, 11 pp., illus. (Technical Report EP-154) June 1961</p> <p>Skin temperatures of semi-nude men were measured during 2-hour exposures to various combinations of air temperature (90 to 25°F) and wind velocities (&lt;1, 5, 10 mph). The data were used to derive an expression for the estimation of mean weighted skin temperature as a function of duration of exposure (up to 180 minutes), air temperature (90 to -20°F), and windspeed (0 to 40 mph). A chart was also constructed for more rapid estimation of skin temperature.</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> <li>1. Body temperature</li> <li>2. Exposure</li> <li>3. Mathematical prediction</li> <li>4. Military personnel</li> <li>5. Military physiology</li> <li>6. Physiology</li> <li>7. Protective clothing</li> <li>8. Skin</li> </ol> <p>I. Title II. Series III. Lampietro, P. F.</p>	<p>AD- Div. 28 Accession No.</p> <p>Quartermaster Research &amp; Engineering Center, Natick, Mass. PREDICTION OF SKIN TEMPERATURE OF MEN IN THE COLD by P. F. Lampietro, 11 pp., illus. (Technical Report EP-154) June 1961</p> <p>Skin temperatures of semi-nude men were measured during 2-hour exposures to various combinations of air temperature (90 to 25°F) and wind velocities (&lt;1, 5, 10 mph). The data were used to derive an expression for the estimation of mean weighted skin temperature as a function of duration of exposure (up to 180 minutes), air temperature (90 to -20°F), and windspeed (0 to 40 mph). A chart was also constructed for more rapid estimation of skin temperature.</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> <li>1. Body temperature</li> <li>2. Exposure</li> <li>3. Mathematical prediction</li> <li>4. Military personnel</li> <li>5. Military physiology</li> <li>6. Physiology</li> <li>7. Protective clothing</li> <li>8. Skin</li> </ol> <p>I. Title II. Series III. Lampietro, P. F.</p>
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